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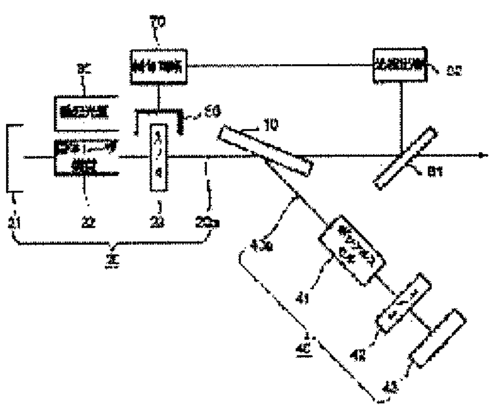
(54) SOLID LASER DEVICE

(57)Abstract:



PROBLEM TO BE SOLVED: To stably control light intensity by providing a first optical system having a first quater wave plate and the like, a second optical system having a second quater wave plate and the like, an exciting means exciting a solid laser medium and a rotation driving means rotating the first quater wave plate around a first optical axis.

SOLUTION: A first optical system 20 is constituted of a polarizer 10, a reflection mirror 21, the solid laser medium 22 and a first quater wave plate 23 on the first optical axis 20a. A second optical system 40 is constituted of the polarizer 10, a

reflection mirror 43, a pocket cell 41 and a second quater wave plate 42 on a second optical axis 40a. A pumping light source 30 light- excites the solid laser medium. The rotation driving part 50 of the rotation driving means rotates the quater wave plate 23 around the first optical axis 20a. A laser beam transmitting through the polarizer 10 is branched by a beam splitter 61 and light intensity is measured by a light sensor 62. A control circuit 70 sets the intensity of the laser beam to a prescribed value by adjusting the rotation azimuth of the quarter wave plate 23 by the rotation driving part 50 in accordance with light intensity.

[Claim(s)]

[Claim 1] The polarizer made to reflect the component of the 2nd polarization bearing which is made to penetrate the component of polarization bearing of [1st] the light which carried out incidence in accordance with the 1st optical axis, and intersects perpendicularly with said 1st polarization bearing in the direction of the 2nd optical axis, The 1st reflecting mirror which has a reflector perpendicular to said 1st optical axis on said 1st optical axis, The solid-state-laser medium and the 1st quarter-wave length plate which were arranged between said polarizer and said 1st reflecting mirror, The 1st optical system which ****, and the 2nd reflecting mirror which has a reflector

perpendicular to said 2nd optical axis on said 2nd optical axis, The Pockels cell and the 2nd quarter-wave length plate which were arranged between said polarizer and said 2nd reflecting mirror, Solid-state-laser equipment characterized by having the 2nd optical system which ****, an excitation means to excite said solid-state-laser medium, and the rotation driving means which rotates said 1st quarter-wave length plate around said 1st optical axis.

[Claim 2] Solid-state-laser equipment according to claim 1 characterized by having further an output light on-the-strength detection means to detect said luminous intensity of the component of the 1st polarization bearing which penetrated said polarizer, and the control means which controls said rotation driving means based on said reinforcement detected by said output light on-the-strength detection means.

[Claim 3] Solid-state-laser equipment according to claim 1 characterized by having further an excitation on-the-strength detection means to detect the reinforcement of excitation by said excitation means, and the control means which controls said rotation driving means based on said reinforcement detected by said excitation on-the-strength detection means.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] A resonator is constituted on both sides of the solid-state-laser medium as a laser active substance, and this invention relates to the solid-state-laser equipment which carries out laser oscillation by exciting this solid-state-laser medium.

[0002]

[Description of the Prior Art] Generally, all the optics, such as a solid-state-laser medium, a Q switch, and a quarter-wave length plate, are arranged in the shape of a straight line, and, as for conventional solid-state-laser equipment, the resonator is constituted. Moreover, what miniaturized the resonator is indicated by JP,56-76587,A by using prism. Drawing 2 is the block diagram of the solid-state-laser equipment currently indicated by this official report.

[0003] This solid-state-laser equipment is equipped with the solid-state-laser medium 102 and a polarizer 103 on the 1st [between the phase shift reflecting mirror 101 and prism 104] optical axis, and is equipped with the Pockels cell 105 and the quarter-wave length plate 106 on the 2nd [between a reflecting mirror 107 and prism 104] optical axis. Here, the phase shift reflecting mirror 101 is a half mirror which has an operation of a quarter-wave length plate simulataneously, and is an output mirror. Prism 104 carries out outgoing radiation of the light which carried out incidence in accordance with the 2nd optical axis in accordance with the 1st optical axis while carrying out outgoing radiation of the light which carried out incidence in accordance with the 1st optical axis in accordance with the 2nd optical axis.

[0004] With this solid-state-laser equipment, in the phase shift reflecting mirror 101, equivalent, a quarter-wave length plate is penetrated, it is reflected by the half mirror, and the light which passed the solid-state-laser medium 102 from the polarizer 103 side penetrates a quarter-wave length plate again. And the light by which induced emission was carried out in the solid-state-laser medium 102 excited by the excitation means in the resonator between the phase shift reflecting mirror 101 and a reflecting mirror 107 goes, comes back to and carries out laser oscillation of the optical-axis top turned up by prism 104 within a resonator.

[0005]

[Problem(s) to be Solved by the Invention] By the way, as for the semiconductor laser light source used as the excitation light source which excites a solid-state-laser medium, a high increase in power is progressing, and researches and developments are done also for solid-state-laser equipment towards a high increase in power and efficient-izing with it. It is required that the oscillation condition in a resonator should be optimized and the

laser oscillation luminous intensity outputted should be controlled to stability at desired value or maximum especially on the occasion of a high increase in power and efficient-izing in solid-state-laser equipment. However, although a certain extent could adjust laser oscillation luminous intensity by controlling an excitation means by conventional solid-state-laser equipment including what was explained by above-mentioned drawing 2 , it was difficult to control laser oscillation luminous intensity to stability.

[0006] This invention is made in order to cancel the above-mentioned trouble, and it aims at offering the solid-state-laser equipment which is stabilized even if it is the case where the laser oscillation light of high power is outputted, and can control reinforcement.

[0007]

[Means for Solving the Problem] The solid-state-laser equipment concerning this invention is (1). The polarizer made to reflect the component of the 2nd polarization bearing which is made to penetrate the component of polarization bearing of [1st] the light which carried out incidence in accordance with the 1st optical axis, and intersects perpendicularly with the 1st polarization bearing in the direction of the 2nd optical axis, (2) The 1st reflecting mirror which has a reflector perpendicular to the 1st optical axis on the 1st optical axis, The solid-state-laser medium and the 1st quarter-wave length plate which were arranged between a polarizer and the 1st reflecting mirror, the 1st optical system which ****, and (3) -- with the 2nd reflecting mirror which has a reflector perpendicular to the 2nd optical axis on the 2nd optical axis The Pockels cell and the 2nd quarter-wave length plate which were arranged between a polarizer and the 2nd reflecting mirror, The 2nd optical system which ****, and (4) An excitation means to excite a solid-state-laser medium, and (5) It is characterized by having the rotation driving means which rotates the 1st quarter-wave length plate around the 1st optical axis.

[0008] According to this solid-state-laser equipment, the inverted population arises in the solid-state-laser medium excited by the excitation means, and when the Q value of the resonator constituted between the 1st reflecting mirror and the 2nd reflecting mirror is set as the small value by the Pockels cell, the number of the inverted population in a solid-state-laser medium increases. On the other hand, if the Q value of a resonator is set as a large value by the Pockels cell, induced emission will arise in a solid-state-laser medium. Although the light of the 1st polarization bearing which carries out incidence to a polarizer in accordance with the 1st optical axis among the light produced by this induced emission penetrates a polarizer, it is reflected in the 2nd

optical axis by the polarizer, and the light of the 2nd polarization bearing goes and comes back to the 2nd optical system which has the Pockels cell and the 2nd quarter-wave length plate, it carries out incidence to a polarizer again, and it is reflected in the 1st optical axis. And the light goes and comes back to the 1st optical system which has a solid-state-laser medium and the 1st quarter-wave length plate, and it carries out incidence to a polarizer again. The polarization condition of the light at this time is a thing according to the rotation azimuth of the 1st quarter-wave length plate in which the roll control was carried out to the surroundings of the 1st optical axis by the rotation driving means. Therefore, the laser oscillation luminous intensity outputted from this solid-state-laser equipment is set as a predetermined value by adjusting the rotation azimuth of the 1st quarter-wave length plate.

[0009] Moreover, the solid-state-laser equipment concerning this invention is (1). An output light on-the-strength detection means to detect the luminous intensity of the component of the 1st polarization bearing which penetrated the polarizer, and (2) It is characterized by having further the control means which controls a rotation driving means based on the reinforcement detected by the output light on-the-strength detection means. In this case, since it is detected by the output light on-the-strength detection means, the 1st light, i.e., laser oscillation luminous intensity, of a component of polarization bearing which penetrated the polarizer, and the rotation azimuth of the 1st quarter-wave length plate is adjusted by the rotation driving means carried out by the control means based on that reinforcement, laser oscillation light is maintained by fixed reinforcement, or is maintained by the maximum reinforcement.

[0010] Moreover, the solid-state-laser equipment concerning this invention is (1). An excitation on-the-strength detection means to detect the reinforcement of excitation by the excitation means, and (2) It is characterized by having further the control means which controls a rotation driving means based on the reinforcement detected by the excitation on-the-strength detection means. In this case, the reinforcement by which a solid-state-laser medium is excited with an excitation means is detected by the excitation on-the-strength detection means, and since the rotation azimuth of the 1st quarter-wave length plate is adjusted by the rotation driving means carried out by the control means based on that reinforcement, even if it changes excitation luminous intensity, laser oscillation light is maintained by fixed reinforcement.

[0011]

[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained to a detail with reference to an accompanying drawing. In addition, in explanation of a drawing, the same sign is given to the same element, and the

overlapping explanation is omitted. Drawing 1 is the block diagram of the solid-state-laser equipment concerning this operation gestalt.

[0012] This solid-state-laser equipment is equipped with a polarizer 10, the 1st optical system 20, and the 2nd optical system 40, and the resonator is constituted. The 1st optical system 20 has the solid-state-laser medium 22 and the 1st quarter-wave length plate 23 on 1st [between a polarizer 10 and the 1st reflecting mirror 21] optical-axis 20a, and the 2nd optical system 40 has the Pockels cell 41 and the 2nd quarter-wave length plate 42 on 2nd [between a polarizer 10 and the 2nd reflecting mirror 43] optical-axis 40a. Moreover, the excitation light source 30 which this solid-state-laser equipment carries out [excitation light source] optical pumping of the solid-state-laser medium 22, and produces the inverted population (excitation means), The rotation mechanical component 50 which rotates 1st optical-axis 20a for the quarter-wave length plate 23 as a medial axis (rotation driving means), The beam splitter 61 which branches in a part of laser oscillation light outputted by penetrating a polarizer 10, It has the photodetector (output light on-the-strength detection means) 62 which detects the branched luminous intensity, and the control circuit (control means) 70 which controls the rotation mechanical component 50 based on the detected optical reinforcement.

[0013] A polarizer 10 makes a p-polarized light component parallel to plane of incidence among the light which carried out incidence along with the 1st optical-axis 20a or 2nd optical-axis 40a penetrate, and reflects an s-polarized light component perpendicular to plane of incidence. The 1st optical-axis 20a and 2nd optical-axis 40a are in symmetric relation mutually to the normal of a polarizer 10, a reflecting mirror 21 has a reflector perpendicular to 1st optical-axis 20a, the reflecting mirror 43 has the reflector perpendicular to 2nd optical-axis 40a, and the resonator is constituted between the reflecting mirror 21 and the reflecting mirror 43.

[0014] For example, Nd element the solid-state-laser medium 22 1.0 at.% addition, if the rod of the YAG crystal carried out is used suitably and optical pumping is carried out by the exposure of excitation light, the inverted population will be produced and induced emission of the light of predetermined wavelength will be carried out. The thing of the high power by which for example, the semiconductor laser light source was suitably used, and the laminating array of the laser diode component was carried out especially is suitable for the excitation light source 30 prepared by approaching in order to carry out optical pumping of this solid-state-laser medium 22. Moreover, since the excitation light source 10 can take a large effective exposure area if it is arranged so that the rod of the solid-state-laser medium 22 may be irradiated from a side face, it is suitable.

[0015] Electro-optics crystals, such as KDP and ADP, are used suitably, and the Pockels cell 41 acts as a Q switch. That is, the Pockels cell 41 modulates the light penetrated according to the value of the electrical potential difference impressed, and, thereby, adjusts the Q value of a resonator. The Q value of a resonator is a parameter showing the amount proportional to the value which broke by consumption energy per cycle the average energy accumulated into the resonator here, when the value is small, excitation energy is stored in the solid-state-laser medium 22, the number of the inverted population increases, on the other hand, when the value is large, induced emission arises and laser oscillation is produced. Moreover, the Pockels cell 41 also does so the operation as a quarter-wave length plate.

[0016] the quarter-wave length plates 23 and 42 -- each is a birefringent plate which gives the phase contrast equivalent to quarter-wave length between perpendicular linearly polarized light components mutually among the light, when light penetrates. It can rotate freely by making 1st optical-axis 20a into a medial axis, a rotation drive is carried out by the rotation mechanical component 50, and the quarter-wave length plate 23 outputs the light of a polarization condition according to the rotation azimuth and polarization condition of input light. If the include angle which the plane of incidence in a polarizer 10 and the optical axis of the quarter-wave length plate 23 make is set to theta and this is made into the rotation azimuth of the quarter-wave length plate 23, namely, the light reflected by the polarizer 10 If the sequential transparency of the quarter-wave length plate 23 and the solid-state-laser medium 22 is carried out, it is reflected by the reflecting mirror 21, the sequential transparency of the solid-state-laser medium 22 and the quarter-wave length plate 23 is carried out and incidence is again carried out to a polarizer 10 at the beginning even if it is s-polarized light Then, it becomes the light which contains an s-polarized light component and a p-polarized light component at a rate according to the rotation azimuth theta of the quarter-wave length plate 23. The rate of the reinforcement of a p-polarized light component is expressed with 4 and sin2 theta-cos 2theta among the light which goes and comes back to the 1st optical system 20, and carries out incidence to a polarizer 10 again. Therefore, the rate of the p-polarized light component which carries out incidence changes to a polarizer 10 in the range from 0% to 100% by changing the rotation azimuth theta of the quarter-wave length plate 23 in the range from 0 degree to 45 degrees.

[0017] In addition, when the percentage of a p-polarized light component is 0% among the light which carries out incidence to a polarizer 10, laser oscillation light must have been outputted from a polarizer 10. Moreover, when the percentage of a p-polarized light component is 100% among the light which carries out incidence to a polarizer 10,

since the light which goes and comes back to the inside of a resonator does not exist, induced emission cannot happen. therefore, the inside of the light which carries out incidence to a polarizer 10 -- the rate of a p-polarized light component -- 0% -- super- -- the maximum output value of laser oscillation light is acquired at the time of which value of less than 100% of range.

[0018] On the other hand, the optical axis of the quarter-wave length plate 42 will output the light of the circular polarization of light, if it is fixed in parallel with the plane of incidence in a polarizer 10, or perpendicularly and the light of the linearly polarized light inputs, and if the light of the circular polarization of light inputs, it will output the light of the linearly polarized light. Moreover, as mentioned above, the Pockels cell 41 also does so the operation as a quarter-wave length plate. Therefore, although the light reflected by the polarizer 10 is s-polarized light at the beginning By penetrating the Pockels cell 41, become the circular polarization of light and it becomes p-polarized light by penetrating the quarter-wave length plate 42. By being reflected by the reflecting mirror 43 and penetrating the quarter-wave length plate 42 again, it becomes the circular polarization of light, and by penetrating the Pockels cell 41, it becomes s-polarized light and, so, all are reflected in the direction of 1st optical-axis 20a by the polarizer 10.

[0019] The beam splitter 41 which inputs the light of the p-polarized light which penetrated the polarizer 10 reflects a part of the light, makes the remainder penetrate, and is taken as the output light of solid-state-laser equipment. A photodetector 42 detects the luminous intensity reflected by this beam splitter 41, and outputs the electrical signal according to that reinforcement, and a photodiode is used. And a control circuit 70 inputs the electrical signal outputted from that photodetector 42, controls the rotation mechanical component 50 based on this electrical signal, and adjusts the rotation azimuth theta of the quarter-wave length plate 23. Thus, according to the feedback system constituted, the laser oscillation light outputted from this solid-state-laser equipment is maintained by fixed reinforcement, or is maintained by the maximum reinforcement.

[0020] Next, an operation of the solid-state-laser equipment concerning this operation gestalt constituted as mentioned above is explained.

[0021] If the excitation light outputted from the excitation light source 30 is irradiated by the solid-state-laser medium 22, the solid-state-laser medium 22 will be excited and the inverted population will produce it in the solid-state-laser medium 22. When the Q value of a resonator is set as the small value by the Pockels cell 41, excitation energy is accumulated into the solid-state-laser medium 22, and the number of the inverted

population increases. And if the Q value of a resonator becomes large, induced emission will happen in the solid-state-laser medium 22.

[0022] Along with 1st optical-axis 20a, incidence of the part of this light by which induced emission was carried out is carried out to the quarter-wave length plate 23, and after it is reflected by the reflecting mirror 21 toward a reflecting mirror 21 along with 1st optical-axis 20a and other parts pass the solid-state-laser medium 22 again, incidence of them is carried out to the quarter-wave length plate 23. The light which penetrates the quarter-wave length plate 23 serves as the p-polarized light component of a predetermined intensity ratio and s-polarized light component according to the rotation azimuth theta of the quarter-wave length plate 23, the light of p-polarized light penetrates a polarizer 10, and the light of s-polarized light is reflected by the polarizer 10.

[0023] It becomes p-polarized light, and is reflected by the reflecting mirror 43, and the light of the s-polarized light reflected in 2nd optical-axis 40a by the polarizer 10 from the 1st optical-axis 20a penetrates the quarter-wave length plate 42 again, it progresses along with 2nd optical-axis 40a, and the Pockels cell 41 is penetrated, it penetrates [it becomes the circular polarization of light and the quarter-wave length plate 42 is penetrated, / it turns into the circular polarization of light] the Pockels cell 41, and turns into s-polarized light. Therefore, it is altogether reflected by the polarizer 10 and this light progresses along with 1st optical-axis 20a.

[0024] The light of the s-polarized light reflected in 1st optical-axis 20a by the polarizer 10 from the 2nd optical-axis 40a progresses along with 1st optical-axis 20a, carries out the sequential transparency of the quarter-wave length plate 23 and the solid-state-laser medium 22, and it is reflected by the reflecting mirror 21, and it carries out the sequential transparency of the solid-state-laser medium 22 and the quarter-wave length plate 23, and they carry out incidence to a polarizer 10 again. When it goes and comes back to the 1st optical system 20 and incidence is again carried out to a polarizer 10, it is the rate of the reinforcement of a p-polarized light component. 4andsin2theta-cos2theta It becomes. That is, the ratio of the reinforcement of the p-polarized light component which should penetrate a polarizer 10 and should serve as laser oscillation light, and the reinforcement of the s-polarized light component reflected by the polarizer 10 is controlled by adjusting appropriately the value of the rotation azimuth theta of the quarter-wave length plate 23. Moreover, since it is reflected by the polarizer 10 and only the light of an s-polarized light component carries out incidence to the Pockels cell 41 among the light which carries out incidence to a polarizer 10, the problem of damage on the Pockels cell 41 is solved.

[0025] Although the light of the p-polarized light which penetrated the polarizer 10 is outputted as a laser oscillation light from this solid-state-laser equipment, that part branches by the beam splitter 61, and is detected by the photodetector 62. The electrical signal outputted from the photodetector 62 according to the detected optical reinforcement is inputted into a control circuit 70. And a control circuit 70 controls the rotation mechanical component 50 based on this electrical signal, and adjusts the rotation azimuth theta of the quarter-wave length plate 23. For example, in controlling so that laser oscillation luminous intensity becomes a predetermined value, the luminous intensity and the reference value which were detected by the photodetector 62 are compared, and it controls the rotation azimuth theta of the quarter-wave length plate 23 so that both value is in agreement.

[0026] moreover, in controlling so that laser oscillation luminous intensity becomes maximum If the luminous intensity which was made to carry out the increment in a minute amount of the rotation azimuth theta of the quarter-wave length plate 23, and was detected by the photodetector 62 increases The increment in a minute amount of the rotation azimuth theta of the quarter-wave length plate 23 is carried out further, the change in optical reinforcement is checked similarly, if the luminous intensity detected by the photodetector 62 decreases on the other hand, minute amount reduction of the rotation azimuth theta of the quarter-wave length plate 23 will be carried out, and the change in optical reinforcement will be checked similarly. Thus, the luminous intensity detected by the photodetector 62 changes the rotation azimuth theta of the quarter-wave length plate 23 in the direction which becomes large.

[0027] This invention is not limited to the above-mentioned operation gestalt, and various deformation is possible for it. For example, by the relation of the laser oscillation luminous intensity to the excitation luminous intensity outputted from the excitation light source 30 being stable, if it is known It changes to the beam splitter 61 and photodetector 62 for detecting laser oscillation luminous intensity. The photodetector (excitation on-the-strength detection means) which detects the excitation luminous intensity outputted from the excitation light source 30 may be formed, the rotation azimuth theta of the quarter-wave length plate 23 may be adjusted according to the result, and laser oscillation luminous intensity may be controlled. In this case, even if it changes excitation luminous intensity, laser oscillation light may be maintained by fixed reinforcement.

[0028] Moreover, by having stabilized the excitation luminous intensity outputted from the excitation light source 30, and the relation of the laser oscillation luminous intensity to the rotation azimuth theta of the quarter-wave length plate 23 being stable, if it is

known Without detecting laser oscillation light and excitation luminous intensity, the rotation azimuth theta of the quarter-wave length plate 23 may be adjusted, laser oscillation luminous intensity may be controlled, and laser oscillation luminous intensity may be set as a predetermined value also in this case.

[0029]

[Effect of the Invention] According to this invention, with as mentioned above, the Q switch by the Pockels cell as explained to the detail Although the light of the 1st polarization bearing which carries out incidence to a polarizer in accordance with the 1st optical axis among the light produced by this induced emission will penetrate a polarizer if induced emission arises in the solid-state-laser medium excited by the excitation means It is reflected in the 2nd optical axis by the polarizer, and the light of the 2nd polarization bearing goes and comes back to the 2nd optical system which has the Pockels cell and the 2nd quarter-wave length plate, it carries out incidence to a polarizer again, and it is reflected in the 1st optical axis. And the light goes and comes back to the 1st optical system which has a solid-state-laser medium and the 1st quarter-wave length plate, and it carries out incidence to a polarizer again. The polarization condition of the light at this time is a thing according to the rotation azimuth of the 1st quarter-wave length plate in which the roll control was carried out to the surroundings of the 1st optical axis by the rotation driving means. Therefore, the laser oscillation luminous intensity outputted from this solid-state-laser equipment is set as a predetermined value by adjusting the rotation azimuth of the 1st quarter-wave length plate.

[0030] Moreover, when the rotation azimuth of the 1st quarter-wave length plate is adjusted based on the 1st light, i.e., laser oscillation luminous intensity, of a component of polarization bearing which penetrated the polarizer, laser oscillation light is maintained by fixed reinforcement, or is maintained by the maximum reinforcement.

[0031] Moreover, when the rotation azimuth of the 1st quarter-wave length plate is adjusted based on the reinforcement by which a solid-state-laser medium is excited with an excitation means, even if it changes excitation luminous intensity, laser oscillation light is maintained by fixed reinforcement.

[Brief Description of the Drawings]

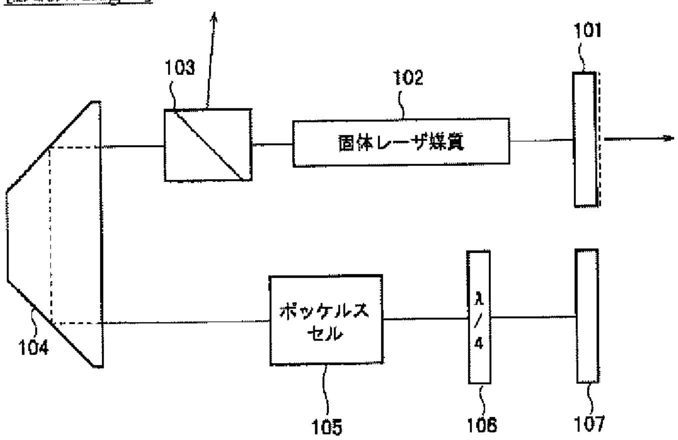
[Drawing 1] It is the block diagram of the solid-state-laser equipment concerning this operation gestalt.

[Drawing 2] It is the block diagram of conventional solid-state-laser equipment.

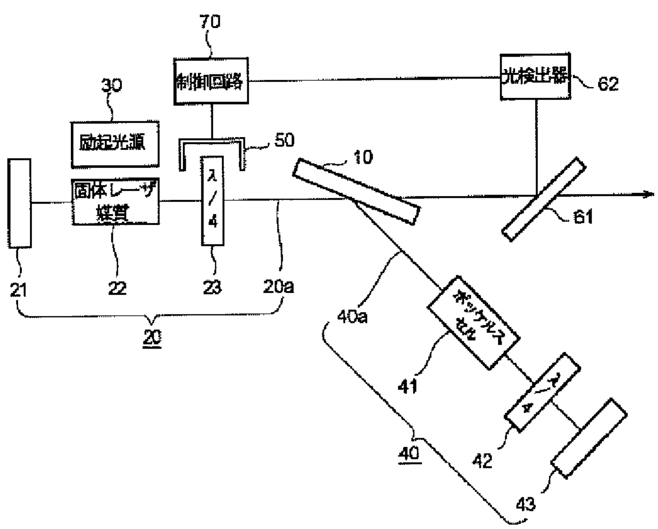
[Description of Notations]

10 [-- A solid-state-laser medium, 23 / -- A quarter-wave length plate, 30 / -- The excitation light source, 40 / -- The 1st optical system, 40a / -- The 2nd optical axis, 41 / -- The Pockels cell, 42 / -- A quarter-wave length plate, 43 / -- A reflecting mirror, 50 / -- A rotation mechanical component, 61 / -- A beam splitter, 62 / -- A photodetector, 70 / -- Control circuit.] -- A polarizer, the 20 -- 1st optical system, 20a -- The 1st optical axis, 21 -- A reflecting mirror, 22

[Drawing 2]



[Drawing 1]



* NOTICES *